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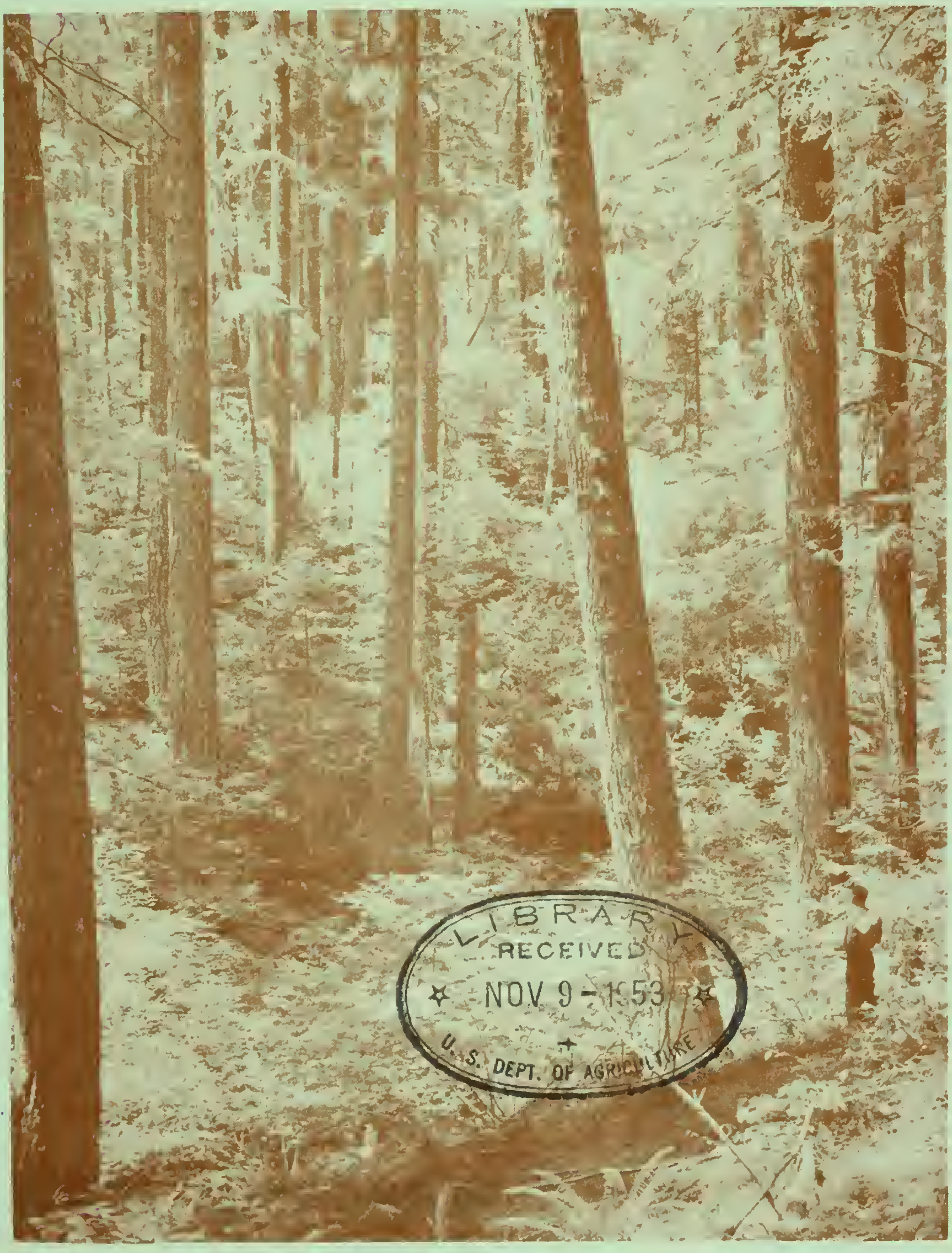
DOUGLAS-FIR REGENERATION

----------a selected and annotated
bibliography for use in California

compiled by **D. F. ROY**



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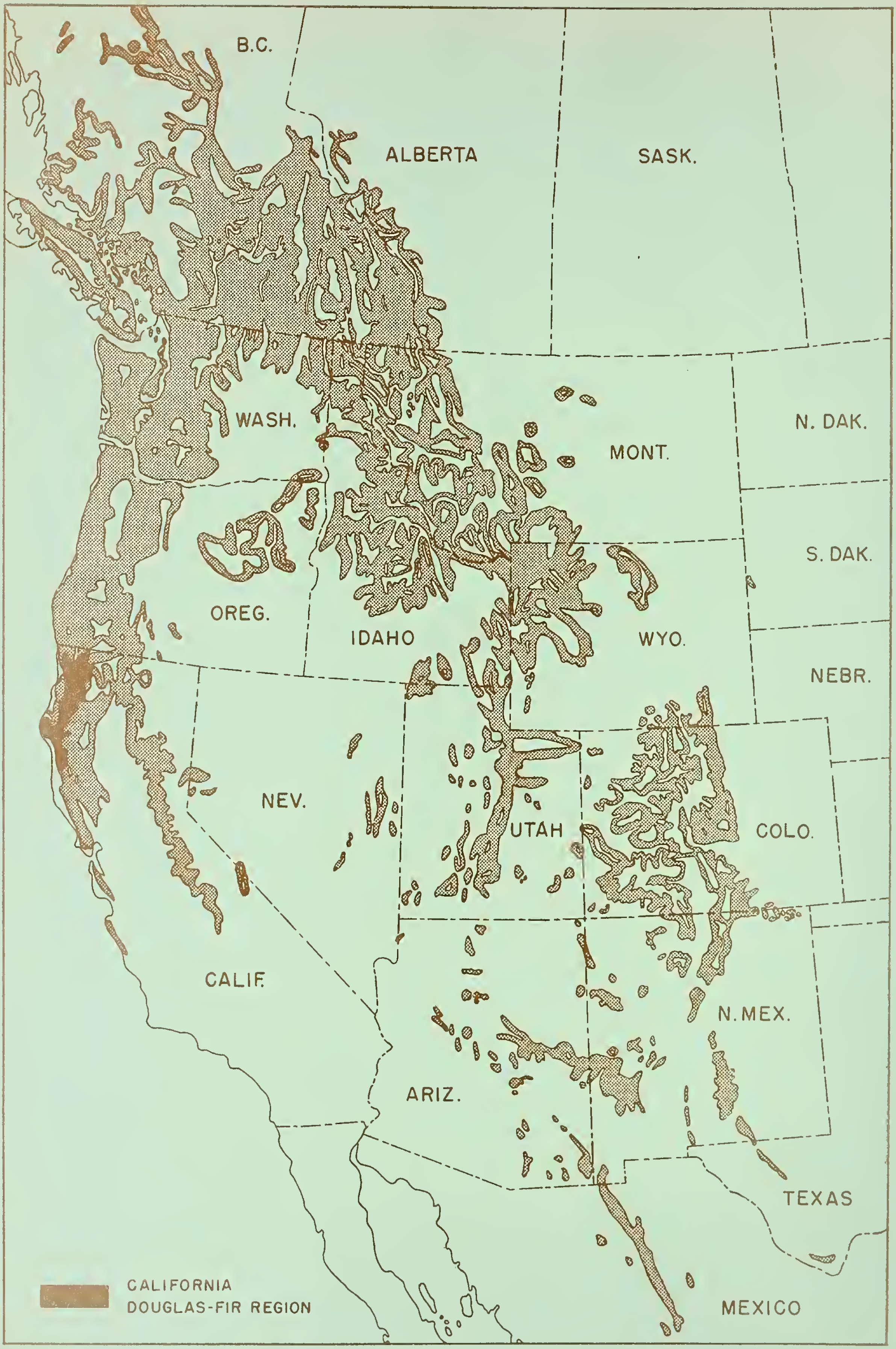

THE NATURAL RANGE OF DOUGLAS-FIR

(From MUNNS, E.N. 1938. The distribution of important forest trees of the United States. U.S. Dept. of Agri. Misc. Pub. 287, 176pp)

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DOUGLAS-FIR REGENERATION

.... a selected and annotated
bibliography for use in California

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DOUGLAS FIR REGENERATION

A Selected and Annotated Bibliography for use in California

Compiled by D. F. Roy[1]

INTRODUCTION

The Douglas-fir (Pseudotsuga taxifolia Britt.) forest type occupies at least 2.6 million acres or 15 percent of the timber croplands in California[2]. In 1946 the volume of Douglas-fir in California was 71.3 billion board feet or 29.3 percent of all timber volume. Douglas-fir led all other species in California lumber production for the first time in 1951; the 1,611 million board feet of Douglas-fir produced was 33.1 percent of the state total[3]. As recently as 1947 the total cut of Douglas-fir in California was only 769 million board feet.

Since World War II logging has accelerated greatly in that part of northwestern California called the California Douglas-fir Region. This region encompasses portions of Del Norte, Humboldt, Mendocino, Siskiyou, and Trinity Counties where Douglas-fir grows in essentially pure stands. The annual Douglas-fir sawlog production increased in this area from 321 to 1,403 million board feet,[4] or 327 percent during 1946 to 1951.

The increased logging has stimulated interest in regeneration in northwestern California. The purpose of this bibliography is to make available selected information which is believed to be pertinent to regeneration of Douglas-fir in California and to indicate to the readers sources of information for certain aspects of regeneration. Most present knowledge of Douglas-fir is based upon observations from the Pacific Northwest and the Southwest. Only American and Canadian references are included because habitat conditions in foreign countries generally differ from those within the natural range of Douglas-fir. Users of the bibliography should remember that findings annotated here may, or may not, apply in California.

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[1] The author is grateful to Mr. Leo A. Isaac, of the Pacific Northwest Forest and Range Experiment Station, who made helpful suggestions after reviewing the manuscript, and to Mr. A. E. Wieslander of the California Forest and Range Experiment Station who furnished the cover photograph.

[2] Wieslander, A. E. and Herbert A. Jensen. 1946. Forest areas, timber volumes and vegetative types in California. U. S. Forest Service, California Forest and Range Experiment Station Forest Survey Release 4. 66 pp.

[3] May, Richard H. 1952. Lumber production in California and Nevada - 1951. U. S. Forest Service. California Forest and Range Experiment Station Forest Survey Release 17. 14 pp.

[4] Data furnished by R. H. May, Division of Forest Economics, California Forest and Range Experiment Station.

Some kinds of information appear in more than one report. To save space such information is generally annotated only once. The annotations are specific except those for one textbook and certain monographs which contain too much information to summarize. In such instances chapter headings are listed. These longer and more comprehensive references should not be overlooked as sources of information.

1. ALLEN, GEORGE S. 1941. A basis for forecasting seed crops of some coniferous trees. Jour. Forestry 39: 1014-1016.

In Douglas-fir as well as a number of other conifers, differentiation of reproductive organs takes place about the time that vegetative growth ceases in the year previous to pollination. Since ovulate, staminate, and vegetative buds can be distinguished by eye, the cone crop can be forecast as a failure or very poor in advance. When the potential seed crop is forecast as fair or better the estimate may be modified by weather conditions, insect damage, and abortions.

2. ______________., 1941. A standard germination test for Douglas-fir seed. Forestry Chron. 17(2): 75-78.

Douglas-fir seed is difficult to test because germination behavior varies. A method of seed testing which decreases this variability and gives a satisfactory measure of seed viability over a short germination period is suggested.

3. ______________. 1941. Light and temperature as factors in the germination of seed of Douglas-fir. Forestry Chron. 17(3): 99-109.

For Douglas-fir, light and temperature (maximums of 21°C. to 35°C.) has little effect upon the germination of stratified seed, or seed which has overwintered on the ground. For unstratified seed, temperature is likely to be a limiting factor in germination, with light intensity being much less important.

4. ______________. 1942. Parthenocarpy, parthenogenesis, and self-sterility of Douglas-fir. Jour. Forestry 40: 642-644.

Douglas-fir may be highly self-sterile. Since pollination and fertilization have no effect upon growth of cones or seed coats, the quality of seed cannot be determined without examining them. Trees less than 20 years old often bear female flowers only. Therefore, an external source of pollen is necessary to produce good seed from young trees. Isolated trees cannot produce quantities of viable seed without cross pollination. Groups of seed trees will produce better seed than isolated trees.

5. ______________. 1942. Douglas-fir, a summary of its life history. Brit. Columbia Forest Service Res. Note 9, 27 pp.

Describes the known life history of Douglas-fir from the production of seed to the growth of adult trees. There must be two conditions before natural reproduction of Douglas-fir can be effective. First, there must be an adequate seed source. Second, the rigorous sites must be alleviated.

6. ______________. 1943. The embryogeny of *Pseudotsuga taxifolia*. Amer. Jour. Bot. 30: 655-661.

Pollen remains in the micropyle about three weeks before it germinates. Fertilization takes place almost nine weeks after pollination.

7. BALDWIN, HENRY IVES. 1942. Forest tree seed of the north temperate regions. Waltham, Massachusetts. 240 pp.

An excellent reference book on forest tree seed. Chapter headings are: Structure and development of tree seeds, seed production of forest trees, seed origin or provenance, seed collection, extraction and cleaning of seed, storage and longevity, biotic enemies of tree seeds, germination, internal factors affecting germination, environmental factors influencing germination, chemistry of seeds and germination, seed stimulation, seed testing, purity analysis, determination of origin, the determination of seed viability without germination, the testing of germination, seed testing stations and seed certification, and tree seed research.

8. BEVER, DALE N. 1952. The relationship of stocking percent to number of trees per acre on artificially seeded areas. Oregon State Board of Forestry Res. Note 9. 9 pp.

A curve, which can be used for converting the percent of milacres stocked to number of trees per acre, is presented. The basic data were obtained from areas which were sown artificially.

9. BRUNNER, JOSEPH. 1915. Douglas-fir pitch moth. U. S. Dept. Agr. Bul. 255. 23 pp.

The pitch-seam type of defect damages 7.5 to 15 percent of Douglas-fir lumber. At least 90 percent of this defect is initiated by the Douglas-fir pitch moth (*Sesia novaroensis*). The pest is most numerous in Douglas-fir stands from 10 to 15 years old which have northerly exposures or which are dense enough to provide almost constant shade. Trees injured from some other cause are infested first. Control suggested is collection of the larvae.

10. CHAIKEN, L. E. 1951. The use of chemicals to control inferior trees in the management of loblolly pine. U. S. Forest Service, Southeastern Forest Experiment Station Paper 10. 34 pp.

Information in this report will be helpful to anyone poisoning unwanted hardwoods in the California Douglas-fir region. Recommendations provide a starting point for treating tanoak and madrone.

The low-volatile esters of 2,4,5-Trichlorophenoxyacetic acid (2,4,5-T) are sold as a liquid concentrate that usually contains the equivalent of 4 pounds of 2,4,5-T acid per gallon and must be diluted for use. The carrier may be either water or oil (such as kerosene, fuel oil, or diesel oil) depending upon the method used. Ammate (ammonium sulfamate) is sold and often used in crystalline form. It can be used in a water solution. Ammate is corrosive to metal, and may cause skin irritation. 2,4,5-T is neither corrosive nor irritating.

Either Ammate or 2,4,5-T can be used as a water solution for spraying foliage. All foliage must be sprayed to the point of runoff. Crystalline Ammate is used in notches cut in the trunk at the base of the tree. The number of notches cut should be equal to one-half the d.b.h. (in inches). A water solution of either chemical can be poured into single-hack girdles of overlapping axe cuts encircling the tree (frilling) at convenient chopping height. Stumps can be sprayed to the point of runoff with an oil solution of 2,4,5-T. Tops and sides of stumps should be treated. Crystalline Ammate can be placed on stump tops. When basal sprays are used, an oil solution of 2,4,5-T is sprayed on a band 24 inches wide around the tree base. Recommended concentrations for various poisoning methods are:

2,4,5-T	
foliage sprays	1 gallon poison to 200 gallons water
frills	1 gallon poison to 50 gallons water
basal sprays	1 gallon poison to 20 gallons oil
stump sprays	1 gallon poison to 20 gallons oil
Ammate	
foliage sprays	1 pound poison to 1 gallon water
frills	2 pounds poison to 1 gallon water
notches	1 tablespoon poison per notch
stumps	1 tablespoon poison per 2 inches of stump diameter

11. CORSON, C. W., and H. A. FOWELLS. 1952. Here's how - a guide to tree planting in the California pine region. U. S. Forest Service, California Forest and Range Experiment Station Misc. Paper 8. 26 pp.

Instructions for seeding and planting given in the guide apply to all conifers. Plantation protection and how to judge plantation success are described.

High sites with no competing vegetation are best. Excessive competing vegetation must be destroyed. Avoid areas where deer or rabbits concentrate. Plant as early in the spring or as late in the fall as possible. Use stock or seed adapted to the site. Consider seed collection zones and age of planting stock. Grade stock for quality. Planting and seeding techniques are discussed in detail.

12. COSENS, RICHARD D., and DAVID TACKLE. 1950. Costs of rodent control in pine regeneration in California. U. S. Forest Service, California Forest and Range Experiment Station Res. Note 73. 5 pp.

Two lethal agents, "1080" (sodium fluroacetate) and thallium sulfate, were used in treating two areas in California prior to seedfall to control seed-eating rodents. Treatment costs were 46 cents per acre in the Sierra mixed-conifer type and 26 cents per acre in the eastside ponderosa pine type of California. These data indicate the costs to be expected for such poisoning in the California Douglas-fir region.

13. COWLIN, R. W. 1932. Sampling Douglas-fir reproduction stands by the stocked-quadrat method. Jour. Forestry 30: 437-439.

The area under examination is divided into squares of such a size that each square can support a tree from seedling to rotation maturity. The size of square should vary with species, age (at rotation), and site. For practical application the four-milacre or 13.2-foot square has been used. The grades of stocking were: good - 70 to 100 percent of the squares stocked; medium - 40 to 70 percent of squares stocked; poor - 10 to 40 percent of squares stocked; and unstocked - less than 10 percent of the squares stocked.

14. DEMBICKI, H. 1953. A recommended regeneration survey system. Univ. of British Columbia, Forest Club Res. Note 7. 9 pp.

The spacing of 8 by 8 feet generally used for plantations in the Pacific Northwest compromises between the lower costs of wider spacing and the silvicultural advantages of closer spacing. At this uniform spacing there would be 680 trees per acre, but the actual numbers range between 600 and 680. Curves show that a standard of 680 trees per acre corresponds to stockings of approximately 40 percent and 70 percent for 1-milacre and 4-milacre quadrats respectively.

The survey system recommended is flexible, using either a 4-milacre plot or four 1-milacre quadrats as needed. For intensive surveys plots or quadrats are spaced one chain apart along strips which are five chains apart. The 4-milacre plots are used to start a strip. Data for groups of five plots are studied as the survey progresses. When stocking approaches the standard of 70 percent the sampling is refined by using four 1-milacre quadrats at each subsequent sampling point. Tally card forms are shown.

15. DUFFIELD, JOHN W. 1950. Techniques and possibilities for Douglas-fir breeding. Jour. Forestry 48: 41-45.

The small amount of exploratory breeding with Douglas-fir is discussed. The techniques adapted from those used for controlling pollination of pines are described. It is harder to collect bulk pollen from Douglas-fir than from pines. The type of pollination has little effect upon the production of normal appearing cones. Therefore, nothing, in regard to success in producing sound seed, can be concluded from cone appearance. Self-fertility appears to be low.

16. FINNIS, J. 1950. Seed maturity in Douglas-fir. Brit. Columbia Forest Service Res. Note 18. 2 pp.

Douglas-fir seed must be thoroughly mature before the cones are picked, or viability of the seed will be very low. Douglas-fir cones do not change in color until just before they open, which may be several weeks after seed have matured. Limited experiments have not shown that specific gravity of cones of Douglas-fir give indications of seed maturity. Embryo size shows promise for indicating mature seed.

7. FOWELLS, H. A. 1946. Forest tree seed collection zones in California. U. S. Forest Service, California Forest and Range Experiment Station Res. Note 51. 5 pp.

The forests of California are divided into forest tree seed collection zones to insure that stock grown is planted in an area with an environment comparable to that of the location in which seed was collected, and to simplify records of seed lots.

3. FOWELLS, H. A., and R. K. ARNOLD. 1939. Hardware cloth seed-spot screens reduce high surface soil temperatures. Jour. Forestry 37: 821-822.

Soil temperatures were measured under a 4-mesh, 20-gauge hardware cloth screen made in the form of a cone 10 inches high and 10 inches across the base. The average maximum temperature outside the cone was 134.3°F. while that inside the cone was 122.1°F. The mean difference of 12.2°F. was statistically significant. Cones might reduce seedling mortality caused by high surface soil temperatures.

. _________, and R. E. STEPHENSON. 1934. Effect of burning on forest soils. Soil Science 38: 175-181.

Burning, which liberates the basic ash materials, stimulates nitrification in forest soil. The immediate effect is to produce a comparatively liberal supply of plant food, for the soluble mineral nutrients are increased. This is favorable both to soil organisms and to plants. After a burn there is likely to be profuse vegetation of wild grasses and herbs. Since the productivity of the forest soil depends upon gradual mineralization of fallen litter, it is not reasonable to expect continuous and often repeated burning to improve forest soil fertility. Burning destroys the organic matter on top of the soil and may destroy some of that in the immediate soil surface.

. FURNISS, R. L. 1943. Biology of *Cylindrocopturus furnissi* Buchanan on Douglas-fir. Jour. Econ. Ent. 35: 853-859.

Cylindrocopturus furnissi is a minor pest of naturally established Douglas-fir reproduction and a potential threat to plantations. Douglas-fir is the only known host. Damage increases under drought conditions. Adults feed upon the inner bark of small branches of Douglas-fir. Natural-control factors are host resistance (pitching out), competition among the larvae, and parasitism. Artificial control is considered unnecessary under forest conditions, but it may become necessary in plantations.

. GARMAN, E. H. 1951. Seed production by conifers in the coastal region of British Columbia related to dissemination and regeneration. Brit. Columbia Forest Service, Tech. Pub. T. 35. 47 pp.

Reports upon seedfall in relation to regeneration under scattered seed trees and on a clear-cut area. Seed production on these two types of logged areas is compared to the production within a mature stand. Mortality of scattered seed trees is discussed.

Summaries for three crops of Douglas-fir cones showed that ratios of surviving seedlings per acre to number of cones produced per acre were, for three plots, 54, 41, and 53 percent. The plot with the lowest survival had the heaviest ground cover.

Even on areas with good seedbeds, well placed old trees bearing good seed crops, produced two cones for each established seedling. On areas of scattered seed trees more seed are required to produce a seedling on poor sites than on good sites, but mature trees produce more seed on poor than on good sites.

Cutover areas which had a residual stand of seed trees regenerated faster than clear-cut areas where the seed was supplied from the margin. Mature residual trees in a cutover area were more efficient seeders than similar trees in an uncut stand. A greater percentage of seedlings survived on cuttings where scattered seed trees were left than on clear-cut blocks. When seed crops of marginal stands are large a smaller proportion of the seed falls on the cutover areas than when the seed crops are smaller.

22. GARMAN, E. H. and A. L. ORR-EWING. 1949. Direct-seeding experiments in the southern coastal region of British Columbia 1923-49. Brit. Columbia Forest Service Tech. Bul. 31. 45 pp.

The deer-mouse (Peromyscus maniculatus) is the greatest single obstacle to the success of direct sowing of Douglas-fir seed. This mouse is present in large numbers on logged-over land and will quickly reoccupy a burned area. Satisfactory direct sowing of Douglas-fir is impossible until some cheap and practicable method of controlling the mouse is devised.

23. GESSEL, STANLEY P. 1950. Correlation between certain soil characteristics and site for Douglas-fir in northwestern Washington. Soil Science Soc. Amer. Proc. 14: 333-337.

The site quality for Douglas-fir can be estimated for alluvial soils. Site index increased with change in soil texture from coarse to light to medium. Depth of soil is important for soils underlain by hardpan or bedrock. Other factors remaining the same, site index increases with increasing mean annual precipitation up to 40 inches.

24. GESSELL, STANLEY P. and W. J. LLOYD. 1950. Effect of some physical soil properties on Douglas-fir site quality. Jour. Forestry 48: 405-410.

Soils of glacial origin were studied. The same conclusions were made as those stated in Reference 23.

25. ________, RICHARD B. WALKER, and PHILIP G. HADDOCK. 1950. Preliminary report on mineral deficiencies in Douglas-fir and western red cedar.

Four approaches were used to determine the mineral requirements of Douglas-fir and Western redcedar. Needs of the species for the usual macronutrients were verified. Characteristic deficiency symptoms for some elements were noted. Nitrogen is important for healthy growth of Douglas-fir. Forest practices conserving nitrogen, or nitrogen fertilization would make tree growth more rapid in second growth stands.

26. HAIG, I. T. 1929. Accuracy of quadrat sampling in studying forest reproduction on cut-over areas. Ecology 10: 374-381.

Sampling forest reproduction by milacre quadrats laid out at intervals along parallel strips running at right angles to the topographic features obtains two important averages: the percentage of area stocked, and the average number of seedlings per acre. It is important to distribute the strips thoroughly over the area. It is more accurate to distribute quadrats along closely spaced strips with larger intervals between quadrats as opposed to widely spaced strips and smaller intervals between quadrats. The recommended method is to count reproduction on milacre (6.6 feet square) quadrats distributed at one-half or one-chain intervals along parallel strips 2.5 to 10 chains apart.

27. ________. 1931. The stocked-quadrat method of sampling reproduction stands. Jour. Forestry 29: 747-749.

The stocked-quadrat method is based on the assumption that if a given area is divided into squares of such a size that one established seedling or tree per square will fully stock the square at maturity, then the percentage of units stocked, regardless of the total number of seedlings per acre, indicates the proportion of land being utilized by tree growth. A method of determining the best size of the sampling unit, when yield and stand tables are available, is presented.

28. HAYES, G. L. 1952. Soil texture can influence forest regeneration from seed. U. S. Forest Service, Tree Planters' Notes No. 11: p. 2.

It appears that cutover tracts on finer soils have better seed germination from either natural seedfall or from direct seeding than cutovers on coarser soil. One reason for the difference may be the greater capacity of fine soils to replace surface water losses by capillary conduction from below. Planting may be a surer method for securing regeneration on coarse soils.

29. HILL, W. W., ALBERT ARNST, and R. M. BOND. 1948. Method of correlating soils with Douglas-fir site quality. Jour. Forestry 46: 835-841.

If the soil is known, production of Douglas-fir can be predicted within narrow limits. Soil units were defined by profile, texture, and depth. The most important factor affecting site quality is the ability of the soil to retain and supply water for tree growth in the dry summer period. Degree of slope did not give a correlation with site-index, but it may be important in influencing temperatures which affect seedling survival on south and west exposures. The soils studied overlay unconsolidated material. (Soils in the California Douglas-fir region overlay consolidated materials.)

30. HOFFMAN, JULIUS VALENTINE. 1924. The natural regeneration of Douglas-fir in the Pacific northwest. U. S. Dept. Agr. Dept. Bul. 1200. 63 pp.

A temperature of 144°F. at the soil surface kills the cambium and causes girdling of Douglas-fir seedlings. Seed will withstand dry heat up to 200°F. and moist heat to 160°F. for long periods.

31. ISAAC, LEO ANTHONY. 1930. Seed flight in the Douglas-fir region. Jour. Forestry 28: 492-499.

Abundance of the crop, height of release, wind velocity, and tree species all influence the distance of seed distribution. Heavy seed fall close to the timber shows that most seed is shed during periods of low wind velocity, but great variations in distance of seed flight may occur. Examples of distances of seed flight are given.

32. ________. 1935. Life of Douglas-fir seed in the forest floor. Jour. Forestr 33: 61-66.

Douglas-fir seed not eaten by birds, insects, or rodents either germinates or decays within a year after it falls.

33. ISAAC, LEO ANTHONY. 1937. Highlights of Douglas-fir natural regeneration. U. S. Forest Service, Pacific Northwest Forest and Range Experiment Station Forest Res. Note 21. 7 pp.

An adequate seed supply is essential for natural regeneration. Almost all the seed is consumed by birds and rodents during years of medium or lighter crops. The average old growth tree left after logging produces about a pound of seed (40,000) during a good year. Eight to ten times this amount is required to seed a single acre (rodents not controlled).

Of the single seed trees left at the rate of two per acre, 75 percent are lost within 10 years by windfall, slash burning, logging, exposure, insect injury, or decay. Best assurance of seed supply is a nearby block of uncut timber.

An area will seed for an average distance of a quarter mile from green timber but air movement is so variable that no positive distance of seed flight can be set for a specific area. First year seedling loss amounts to from 66 to 95 percent. Causes of mortality listed in approximate order of importance are: heat injury, drought, rodents, frost, insect injury, and competition.

34. ISAAC, LEO ANTHONY. 1938. Factors affecting establishment of Douglas-fir seedlings. U. S. Dept. Agr. Cir. 486. 46 pp.

Reports on the environmental factors of air and soil temperatures, evaporation and solar radiant energy, soil moisture, and precipitation. Also observed were the effects of shade, plant competition, exposure, slash burning, and attack by biologic enemies, such as mice, cutworms, and strawberry weevil. Immediately after germination seedlings are easily injured by heat at the soil surface. This heat is influenced by shade, exposure, soil moisture, and soil color. Surface-soil temperature of 123°F. is likely to injure Douglas-fir seedlings within several days after germination. Temperatures of 123°F. occur on natural soil surfaces when air temperature is 80°F. Seedlings are also injured by frost, either directly or through soil heaving. Wilting-coefficient tests indicated that first-year seedlings die of drought at soil moisture contents of 5 to 12 percent. The wilting point averaged 10 percent. This publication has a good review of literature and covers its field very well.

35. _________. 1940. Vegetative succession following logging in the Douglas-fir region with special reference to fire. Jour. Forestry 38: 716-721.

In Douglas-fir forests there may be distinct age classes occurring more or less groupwise, but there will not be an all-age forest unless the intermediate ages are made up of the more tolerant species that come in as an understory. If younger Douglas-firs occur in a stand they developed because part of the original forest was removed by fire, wind, insects, or disease. Cover density affects the rate of natural reforestation on cutover lands. Light shade from vegetation is desirable for tree seedling establishment, but cover soon begins to compete with tree seedlings for moisture and growing space. This appears to start when cover density approaches 25 percent. As vegetation increases, competition becomes more detrimental, and beyond 85 percent density it is almost impossible for seedlings to become established unless they occur in small open spots. If seedlings get started when cover is light they may continue to grow when cover becomes heavy.

Successive fires impoverish the soil, favor the herbaceous species, retard the brush species, and eliminate the coniferous seedlings which would make the new forest.

36. _________. 1943. Reproductive habits of Douglas-fir. Charles Lathrop Pack Forestry Foundation, Washington, D. C. 107 pp.

A very good compilation of knowledge in this field. Most of the information presented is noted in other references; some other points: Cone crops are generally heavier on poor sites than on good sites. Cones start to open and shed their seed about September 1. Cones open in dry weather and partially close in moist weather so the period of dissemination varies with the weather. Normally two-thirds of the seed falls before the end of October. The remainder drops during late fall, winter, or spring. In mild weather seedlings can live with a lower soil moisture than in hot weather.

37. ________. 1949. Better Douglas-fir forests from better seed. University of Washington, Seattle, Washington. 65 pp.

The means of securing the best natural strain of Douglas-fir seed for each reforestation area--considering both climate and soil--and information to assist in growing Douglas-fir are given.

Wild strains of Douglas-fir have distinct climatic and soil limitations. Seed from such strains should not be used beyond these limits. Strains may vary in tree form, growth rate, hardiness or other characteristics, or a combination of them.

A good stand of well-formed trees growing in a climate like that of the planting site is the most important requisite for a seed source. On irregular terrain climate is not determined by elevation and latitude alone so climatic records and topography must be correlated. Suggested rules for Douglas-fir seed collection are:

1. Collect seed within a hundred miles north or south of planting site if at a similar elevation.

2. A 500-foot rise or drop in elevation is allowable if seed source is not more than 10 miles to the north or south.

3. For each additional 10 miles north of planting site the allowable elevation for seed collection is reduced by 50 feet, up to 100 miles north.

4. For each additional 10 miles south of planting site the allowable elevation for seed collection is increased by 50 feet, up to 100 miles south.

5. In a rough, broken country climate should guide more than distance or elevation. Average annual temperature of the seed source should be within 2°F., plus or minus, and the frost-free period should be similar to that of the planting site.

6. The seed-source stand should be thrifty and making average or better than average growth for the locality.

7. Individual seed trees should be of good form and should not be excessively limby.

The length of growing period is partially determined by inheritance rather than by weather conditions alone. To obtain maximum tree growth in a plantation, the seed used to produce the planting stock should be collected just a little south of the planting site, or at a slightly lower elevation. The planted trees will have a longer growing period than trees native to the site but will not be injured by low temperatures.

Density of seedfall varies inversely with the distance from the seed source. Normally seed will be distributed in sufficient density for restocking to a distance of a quarter mile from old-growth timber. Heavy crops come at 5- to 7-year intervals with about one complete crop failure and two or three each of light and medium crops intervening.

Douglas-fir seed can be held in cold storage up to 10 years without serious loss of vitality.

38. ________. 1952. Advantages of selecting tree seeds with care. U. S. Forest Service, Tree Planters' Notes No. 11: 5-11.

Normally the cost of seed is not more than 1 to 2 percent of the planting cost per acre. Since strains of Douglas-fir vary in tree form, growth rate, hardiness, or other characteristics which are transmitted from parents to progeny, and since seed collection costs are such a small amount of the total cost of planting stock production, it pays to collect seed from the best trees available.

Climatic limitations have been recognized. Average annual and minimum temperatures, and summer rainfall are most important. Trees moved to a climate with more than a few degrees colder minimum temperature are often killed by frost when winter temperatures are colder than average. Comparable rainfall just prior to and during the growing season is far more important than equal annual precipitation.

Identifying superior stands or superior individual trees is not as certain as determining climatic limitations. Following is a tentative list of superior tree characteristics:

1. Faster growing than neighbors or faster than the average in a stand.

2. Full and vigorous crown, but with fewer and smaller limbs on the lower crown than neighbors or than the average of the stand.

3. Clean straight bole with good form.

4. Needles and crown thrifty and full, but not overly dense.

5. Long clear spaces between nodes.

6. Limbs in upper crown should stand at right angles to the stem or droop slightly rather than point upward.

Until specific superior strains have been identified for localities and seed collection areas designated and improved, the best formula for getting the best seed for a given site is as follows:

1. Select a better than average (or the best) stand in the vicinity of the planting site where seed collection is possible. Within a 100-mile limitation, a good stand is more essential than closeness to planting site.

2. Seed from an equal or slightly lower elevation is said to give the best growth rate although considerable leeway is permissible.

3. Gather cones, not from the trees with the heaviest crop, but from those with best form and growth rate. Since trees are cross pollinated, all will produce some good, some average and some poor seedlings, but the highest percentage of good trees is likely to come from the best parent.

39. __________, and HOWARD G. HOPKINS. 1937. Forest soil of the Douglas-fir region, and changes wrought upon it by logging and slash burning. Ecology 18: 264-279.

Douglas-fir cutover areas commonly have great accumulations of slash. On several operations slash per acre averaged 24,000 cubic feet, including 15,000 cubic feet of small branch wood, twigs, chips, bark, and slabs. Light slash fires consume about 90 percent of the branch wood and about 10 percent of the larger slash material. This reduces the immediate fire hazard, but also destroys the protective soil covering and the future source of soil organic material. Burning slash accumulations produce extremely high temperatures which last for several hours.

Burning reduces soil acidity, consumes humus, reduces moisture-holding capacity, drives off most of the nitrogen, and leaves the remaining plant foods in a readily soluble form so that they are used up quickly or leached out. Roughly, changes in the soil are proportional to the intensity of the burn.

Blackening of the soil surface by burning greatly increases the heat-absorptive capacity of the soil, and can cause soil temperatures to rise high enough to kill tree seedlings at times when the surface temperature of soil on unburned areas causes no injury to seedlings.

The great quantity of plant food available in the surface soil for a year or more after a slash fire may have an undesirable effect on Douglas-fir regeneration. First-year seedlings tend to develop luxuriant crowns and small, shallow root systems, which make them unfit for withstanding the annual summer drought.

Harmful effects of the ordinary slash fire more than outweigh any beneficial effects it may have on the productivity of Douglas-fir soil. Harm done is roughly proportional to the completeness with which the fire consumes duff and organic material in the surface soil.

40. ISAAC, LEO A., and GEORGE S. MEAGHER. 1936. Natural reproduction on the Tillamook burn two years after the fire. U. S. Forest Service, Pacific Northwest Forest and Range Experiment Station. 19 pp. (Mimeo.)

Green trees seeded areas for a radius of 10 chains reasonably well. Slope and exposure had a decided effect on establishment and survival of reproduction. Restocking conditions depended upon the intensity of the fire. The less intense the fire, the more complete was the restocking.

41. JEWESSON, R. S., and W. DANYLUK. 1951. The comparative viability of seeds from different parts of the cones of interior Douglas-fir and lodgepole pine. Univ. Brit. Columbia Forest Club Research Note 4. 4 pp.

Except in the extreme basal scales, all parts of the cones of Douglas-fir can produce viable seed. All scales bearing good seed open at approximately the same time. There were no significant differences in germination between seed from 3 different parts of the cones.

42. KEEN, F. P. 1952. Insect enemies of western forests. U. S. Dept. Agr. Misc. Pub. 273. 280 pp.

This manual describes the insects found in forests west of the Great Plains. The western forest trees are followed through their life cycle, from seed to final product, and at each step the insects of greatest importance are discussed. Cone moths, seed chalcids, wireworms, cutworms, white grubs, the Douglas-fir twig weevil, twig moths, aphids, tussock moths, loopers, budworms, and pitch moths are included.

43. KRAUCH, HERMAN. 1936. Some factors influencing Douglas-fir reproduction in the Southwest. Jour. Forestry 34: 601-608.

By safeguarding the seed supply against rodents, preparing a suitable seed bed, eliminating excessive root competition and providing the right degree of light and shade, reproduction of Douglas-fir is assured. Rodent control is the most important. Mineral soil is the best seedbed. Seed should be covered with soil and extensive herbaceous vegetation should be removed. Light or moderate shade favors both germination and survival.

44. KRAUCH, HERMAN. 1937. Use of protective screens in seed-spot sowing found to serve two-fold purpose. U. S. Forest Service, Southwestern Forest and Range Experiment Station Res. Note 22. 3 pp.

Besides protecting seed and seedlings from rodents and birds (mainly Juncos) screens partially shade tender new seedlings. Beneficial effect is especially indicated by survival of seedlings from screened seed spots sown on south slopes.

45. ________. 1938. Covering seed spots with screens still remains the only effective method of deflecting rodents. U. S. Forest Service, Southwestern Forest and Range Experiment Station Res. Note 29. 2 pp.

Five methods of protecting seed spots were tried. Of these, screens gave the only effective protection from rodents. Cellophane cylinders and a rodent repellent were two of the unsuccessful methods.

46. _________. 1938. Does screening of seed spots do more than protect the spots against rodents and birds? U. S. Forest Service, Southwestern Forest and Range Experiment Station Res. Note 49. 4 pp.

Infers that screening seed spots has ameliorating effect on physical factors, besides giving protection from rodents and birds.

47. _________. 1938. Seedlings safe from rodent destruction after a year's protection. U. S. Forest Service, Southwestern Forest and Range Experiment Station Res. Note 43. 5 pp.

Mice damaged only seedlings whose stems had not yet lignified.

48. _________. 1942. Scarifying soil to promote natural regeneration in Douglas-fir cut-over stands shows no marked benefit. U. S. Forest Service, Southwestern Forest and Range Experiment Station Res. Note 101. 2 pp.

Rodents, chiefly mice, were responsible for inadequate restocking of Douglas-fir cut-over lands. Scarifying the soil immediately after seed fall was of some benefit, but not sufficiently so to justify the treatment. Of much greater significance is rodent poisoning. One poisoned area had more than ten times the number of seedlings on a non-poisoned area.

49. KRAUCH, HERMAN. 1945. Influence of rodents on natural regeneration of Douglas-fir in the southwest. Jour. Forestry 43: 585-589.

When rodents had been effectively controlled, sufficient numbers of seedlings survived. Rodents can be effectively controlled by poisoning. Poisoning cut-over areas in good seed crop years is recommended. Large areas must be treated to prevent rapid reinvasion. Supplementary treatment would probably be unnecessary because seedlings a year old are not susceptible to rodent destruction.

50. KUMMEL, JULIUS F., CHARLES A. RINDT, and THORNTON T. MUNGER. 1944. Forest planting in the Douglas-fir region. U. S. Forest Service, Pacific Northwest Region, Portland, Oregon. 154 pp.

All phases of seed collection, extraction, storage, and testing, nursery practice, field planting, care of plantations, and direct seeding are discussed. Some findings which are not annotated elsewhere follow:

Records in the Pacific Northwest show cone crops for 33 years as 7 failures, 13 light, 6 medium, and 7 abundant crops. The seed collection period commences earliest at low and intermediate altitudes toward the southern part of the region, and lasts two or three weeks between the last week in August and the latter part of September. Seed must be mature when collected. As seed matures, the seed coat darkens and the kernel changes from a milky consistency to a firm pulp with a light yellowish-green embryo in the center. Roughly, each good seed exposed in a length-wise section of a Douglas-fir cone represents an ounce of clean seed to every bushel of cones. Tests with planting stock have shown that diameter of stems at the ground surface is the best mensurational index of quality of stock and its likelihood of surviving.

51. LANTELME, W. 1938. Method of inducing fruiting of forest trees. U. S. Forest Service. Washington, D. C. Translation 364. 8 pp.

Induced fruiting of beech by girdling. Data not adequate for making conclusions.

52. LAWSON, A. A. 1909. The gametophyte and embryo of *Pseudotsuga douglasii*. Ann. Bot. 23: 163-180.

Pollination takes place early in April or the latter part of May and lasts two or three weeks. The pollen grains remain in the upper chamber of the micropyle for a week or ten days before germination begins.

53. McARDLE, R. E. 1930. Effect of fire on Douglas-fir slash. Jour. Forestry 28: 568-569.

Logging in Douglas-fir stands results in leaving about 155 cords (100 cubic feet to the cord) of wood debris of all kinds per acre. Snags and unmerchantable trees not felled may blow down and materially increase the volume of debris. Large pieces, more than 3 inches in diameter and 3 feet long, account for 5 to 140 cords per acre. A reasonably efficient logging operation leaves about 62 cords of large material in about 335 pieces. Small pieces account for 40 to more than 200 cords, or an average of 90 cords. The average acre also has 3 or 4 cords of rotten logs.

A slash fire removes 9 to 49 percent of the volume of the large pieces, depending upon the severity of the fire and age of the slash. In fresh slash a fire probably burns no more than 30 percent of the larger pieces. Fire doesn't reduce the diameter of the larger pieces, instead, it burns entire sections from them, especially when cull logs and down trees or snags are crossed.

A heavy fire consumes at least 95 percent of the volume of small material. Even a light fire in fresh slash removes about half the branchwood and other small pieces.

54. __________, and LEO A. ISAAC. 1933. The ecological aspects of natural regeneration of Douglas-fir in the Pacific northwest. Pacific Sci. Cong. Proc. 5: 4009-4015.

Ordinarily seed production is uniform throughout the region, but in some years it is very uneven. Under normal conditions, viable seed fall in sufficient quantity for restocking only within 1,000 feet from standing timber. Unusual air currents may carry seed much longer distances. On some cut-over areas, 66-95 percent of the annual seedling crop dies from one cause or another. These causes listed in order of importance are: heat injury to the stem, drought, rodents, competition of other vegetation, and frost. Heat injury begins when surface soil reaches 123°F. if the seedlings are less than a week old. Drought is serious and occurs during late summer. White-footed mice have a liking for foliage of newly germinated seedlings. Frost in the spring kills tender young seedlings while frost in the fall causes loss through soil heaving. Temperatures have the greatest effect on survival. Among factors affecting temperatures are soil color and the presence or absence of shade. Slash burning is detrimental to natural regeneration. Seed or seedlings on the ground at the time of cutting may be destroyed, soil temperatures are raised (by changing soil color), evaporation is increased, soil moisture is reduced, fertility of the soil is lessened, and a distinct type of minor vegetative cover which offers serious competition to the young seedlings is created. Advantages of slash fires are reduction of the rodent and insect population, and removal of excessive logging debris and excessive vegetative cover.

55. ________, WALTER H. MEYER, and DONALD BRUCE. Rev. 1949. The yield of Douglas-fir in the Pacific Northwest. U. S. Dept. Agr. Tech. Bul. 201. 74 pp.

The stocking, growth, and yield data given help those interested in timber crops to determine the profitableness of timber growing on various classes of land, to decide upon the best age at which to cut the timber, to predict the probable future size of the trees, and to estimate the prospective value of the crop.

Douglas-fir is able to establish itself more successfully by natural means in open areas caused by fire or logging than any of its associates. Although a new forest starts with many thousands of small trees to the acre, only a small proportion of these survive until the stand reaches maturity. On reasonably good land there should be about 900 ten-year-old trees per acre, some being 10 or 12 feet high.

Douglas-fir cannot live in heavy shade, and for this reason there are no young Douglas-firs in the understory to take the place of the old trees as they die. Species such as white fir which can grow in the shade of the mature forest fill in the openings left by dying Douglas-fir.

Early in life Douglas-fir is able to withstand some side shading, but after about the twenty-fifth year it is unable to grow satisfactorily or to live in either side or overhead shade. Sensitiveness to shade varies with age and growth conditions. Young trees are more tolerant than old trees and trees having good growth conditions are more tolerant of shade than those on the poorer sites.

Young Douglas-fir has been fairly free from fungus diseases and tree-killing insects. The only serious insect attacks have been near the marginal limits of the tree's distribution. Ice storms occasionally break the tops out of trees, those trees so damaged seldom recovering their places in the forest canopy. Crown fires sometimes destroy many acres of Douglas-fir forests, but are rare in young stands, while surface fires do little damage to mature trees protected by their thick bark, but damage young stands by scarring the bases of the thin-barked trees, exposing them to windthrow and fungus attacks.

Douglas-fir normally is a deep-rooted species on the drier loams and very dry gravels, but the character of the root system seems to be determined mainly by the availability of moisture in the soil. On wet clay soils so shallow a root system develops that isolated trees are subject to windthrow. Windthrow is particularly prevalent in the wet soils of river bottoms.

Higher altitudes shorten the growing season and lower the mean temperature, thereby reducing productivity. Aspect is also an important factor regulating growth. The most rapid growth is found on north, northeast, and east aspects. Soils have a major influence on productivity. The most rapid growth and largest yields are obtained on deep, well drained sandy loam soils. Clay soils rank second, and gravelly soils are the least productive. If soils and elevations are favorable the most productive areas are those where the annual precipitation is more than 60 inches. If rainfall is less than 30 inches annually the trees grow slowly and the yields are small.

The completeness of stocking has a decided effect upon the volume production and the quality of wood produced. When trees are closely spaced the limbs on the lower portions of the stems remain small and die early because of shading, and the lumber from closely grown trees, therefore, has fewer and smaller knots, a finer texture, and a higher quality.

56. McKINNON, F. S. 1937. A discussion of the effects of slash burning on the regeneration of Douglas-fir. Brit. Columbia Forest Service Res. Note 1. 3 pp.

Burning is recommended where a combination of the following conditions are found: (1) Heavy slash--apart from the hazard, excessive slash covers so much land surface that the young stand will be poorly stocked and of poor quality due to mechanical interference of the debris, (2) heavy duff--removal improves seedbed, (3) seed supply--a source of seed, either marginal timber or groups of seed trees within seeding distance is essential. Burning is not recommended where slash is light and the seedbed is satisfactory.

57. MILLER, JOHN M. 1914. Insect damage to the cones and seeds of Pacific Coast conifers. U. S. Dept. Agr. Bul. 95. 7 pp.

Symptoms and causes of blighted cones, wormy and aborted cones, wormy seed, and maggoty cones are explained. Important groups of seed-infesting insects are described. Included are cone beetles, cone worms, seed chalcids, and fir-cone maggots. One species of cone-worm is very common to Douglas-fir, and one species of seed chalcid is very destructive to Douglas-fir seed.

58. MILLER, JOHN M. 1916. Oviposition of Megastigmus spermotrophus in the seed of Douglas-fir. U. S. Dept. Agr. Jour. Agr. Res. 6: 65-68.

Describes oviposition which occurs in April or May when the cones are young, about 1½ inches long, the scales still soft, and the seeds with milky interior and unhardened coat.

59. MOORE, A. W. 1940. Wild animal damage to seed and seedlings on cut-over Douglas-fir lands of Oregon and Washington. U. S. Dept. Agr. Tech. Bul. 706. 28 pp.

Seed eaters: White-footed mice (*Peromyscus* spp.) consume more conifer seed in the Douglas-fir region than any other animal. They are always present, and are active both in summer and winter. Burns are soon repopulated. Chipmunks also consume many conifer seed. Shrews (Sorex spp.) can eat as many as 100 Douglas-fir seed in a night. The shrew-mole, or Gibbs mole(*Neurothrichus gibbsii*) has the same seed-eating habits. Squirrels are not important.

Animals that affect growing trees: In the Douglas-fir region rabbits, more than any other animal, retard growth of young trees by cropping them. The redwood brush rabbit (*Sylvilagus bachmani ubericolor*) and the Washington varying hare, or snowshoe rabbit, (*Lepus washingtonii*) are very destructive. Almost all trees and shrubs common to the region are browsed by these two rabbits. The mountain beaver (Apoldontia spp.) crops in the same manner as the browsing rabbits but also climbs, delimbs, and tops small saplings.

60. MOORE, A. W. 1942. Shrews as a check on Douglas-fir regeneration. Jour. Mammal. 23: 37-41.

Douglas-fir seed are readily consumed by shrews (Sorex spp.). Slash burning destroyed shrews. Shrews can pass through a 1/2-inch mesh screen at will, but 1/3-inch mesh will keep them out. Hull remnants of Douglas-fir seed eaten by mice differ from those chewed by shrews. Mice remove very little of the hull and make a clean cleavage. Shrews leave serrated edges. Shrews must sample each seed to determine whether the kernel is present. Mice differentiate between good or bad seed by merely picking it up. Both kernels and hulls of Douglas-fir seed contain odors attractive to white-footed mice (*Peromyscus* spp.) Mice hunt out both kernels and hulls by smell.

61. MORRIS, WILLIAM G. 1932. The effect of high temperature and moisture content upon seed from Douglas-fir and western yellow pine. (Thesis, M.S., University of California) Berkeley, California. 33 pp.

When seed of Douglas-fir and western yellow pine is heated, the resistance to thermal injury decreases as the moisture content of the seed increases. Germination percent, twenty days after sprouting began, did not show a significant difference in the effect of various heat treatments; but at the end of sixty days, the difference was readily apparent. Lowest temperatures which caused significant loss of viability under given conditions of seed moisture content and duration of heating are tabulated.

62. MUNGER, THORNTON T. 1943. Vital statistics for some Douglas-fir plantations. Jour. Forestry 41: 53-56.

After plantations have passed the tender period of establishment they may be damaged by fire, mountain beaver, deer, bear (strip bark about the bases of trees 8 inches or more in diameter), snowbreak, winter kill (consequence of planting the wrong strain), falling snags and bark, and competing vegetation.

63. ________, and DONALD N. MATTHEWS. 1941. Slash disposal and forest management after clear cutting in the Douglas-fir region. U. S. Dept. Agr. Cir. 586. 56 pp.

Disposal of the enormous quantity of slash left after clear-cutting is desirable as a fire-protection measure because it removes some of the fire hazard, facilitates subsequent fire control, and reduces the chance of disaster from an uncontrollable fire. Broadcast burning is the only practicable method of slash disposal, but is effective only when a high percentage of the fine fuels are consumed without killing standing trees. The rate-of-spread factor is immediately reduced by slash burning, but the vegetation builds up again so that in about six years it is the same on burned as on unburned areas. The resistance-to-control factor is less on burned areas for many years. Combining the two factors shows that unburned areas are 18 times more hazardous than comparable areas immediately after burning, but that hazard is equalized in about 20 years. Broadcast burning has several disadvantages. It lessens the chance for quick and adequate natural reforestation because it kills advance reproduction, potential seed trees, and often some adjoining timber, and also destroys seed on the ground. Unburned areas, in general, attain a given degree of stocking 3 to 5 years quicker than burned areas. Burning also destroys sources of shade beneficial to tender seedlings, and may impair the physical or chemical condition of the soil. Chances for soil erosion and rapid run-off may be increased.

The effects of slash burning upon insect infestations, grazing use, and game management, are inconsequential so far as known. A slash fire does not rid an area of mice. In fact, slash burning seems to encourage small rodents on some areas by making it easier for them to find seed of trees or other vegetation after the litter has been burned off. Rabbits, which often damage tree seedlings, are attracted to some areas by the succulent sprouts and herbs which come in after the burn.

Slash should be burned where:

1. The chances of accidental fires are high or the opportunities for fire control are poor.

2. The cutting is clean and there is no understory that would be killed to make another hazard comparable to the initial slash.

3. The fire hazard is high because the area has very extensive areas of recent cuttings.

Do not burn slash where:

1. A considerable reserve stand or understory would be killed by fire, making little net gain in reducing the fire hazard.
2. The logged area is well isolated from risk of fire and is not a particularly high hazard in itself.
3. A good stand of advance or subsequent reproduction promises to give shade and reduce fuel inflammability in a very few years.

64. _________, and WILLIAM G. MORRIS. 1936. Growth of Douglas-fir trees of known seed source. U. S. Dept. Agr. Tech. Bul. 537. 40 pp.

Seed of Douglas-fir was collected in 13 different localities in the western parts of Washington and Oregon in order to test hereditary traits. Parent trees were selected so that younger trees and older trees, trees growing on good and on poor sites, open-grown trees and crowded trees, fungus infected trees and uninfected trees, and trees at high and low altitudes were all represented. After two years in the nursery progeny of these trees were out-planted in four localities at four different elevations. Measurements were made through either 16 or 17 growing seasons after planting. No parent characteristics seemed to affect the seed viability. However, the largest cones and seed were produced by young trees and on the more vigorous branches of any given tree. Seedlings from large seed were slightly taller at the end of the first year than those from small seed, but the latter caught up during the second year.

Height growth of the progeny was not affected by the age of the parent tree, the quality of parent's growing site, parent's growing space or the condition as to fungus infection of the parent tree. On the average there was little difference between height growth of progeny of different parents of the same location. Mortality in the plantations was not affected by seed source. There were marked differences in the dates when progeny burst leaf buds. This is important because of the potential frost damage to early opening buds.

Progeny from two seed-source locations made outstanding height growth on every plantation. Since no characteristic of the parent trees as individuals was found to explain it, this outstanding growth was attributed to an inheritable vigor characteristic of a strain or race. One stock from high altitude made much less growth than the average of all stocks at low elevation, but grew better than average at a high altitude. In contrast, a stock from the coastal hills made less growth than the all-stock average in the high-altitude plantation, but grew much better than average in the coastal plain. Several stocks grew equally well, in comparison with the average, on each of the four plantation areas.

65. NEUNS, ALVA G. and ALBERT SIMPSON. 1951. The use of 2,4-D and 2,4,5-T for brush control on California roads and trails. U. S. Dept. Agr. Forest Service (Region 5). 27 pp.

Includes instructions for ordering chemicals, costs, adjusting concentrations, time to spray, how to spray, and spraying equipment.

66. ORR-EWING, A. L. 1950. Life history of the deer mouse. Forestry Chron. 26(2): 115-126.

The deer or white-footed mouse (Peromyscus spp.) population is lowest in the early months of the year and does not show marked increase until breeding becomes general in April or May. The population then rises steadily until a peak is reached in October or November.

67. ________. 1950. Rodent control in direct seeding through use of poisons. Brit. Columbia Forest Service Res. Note 17. 8 pp.

Rodent control with the poison 1080 (Sodium fluoroacetate) appears to have very good possibilities. It is unlikely to have harmful effects on other wildlife provided it is used carefully.

68. RADCLIFFE, D. N. 1952. An appraisal of seed damage by the Douglas-fir cone moth, in British Columbia. Forestry Chron. 28(2): 19-24.

The adult of the Douglas-fir cone moth (Barbara colfaxiana) is an inconspicuous grey moth measuring approximately two centimeters in wing span. The forewings are flecked, or mottled, with light grey or silver. The wing margins are distinctly hairy in appearance.

The moths emerge in April and lay eggs on the bracts of the still immature cones. The caterpillars on emergence, bore into the scale tissues and feed within the cone throughout the summer until late July or August. Most caterpillars pupate by the end of August, but a few persist into late September. Mature caterpillars are pink and are about two centimeters long. The insect overwinters as a pupa in a pitch-coated cocoon secured to the scale close to the cone axis.

A single caterpillar destroys about 45 percent of the seed in a cone. Two larvae destroy 75 percent, and three or more destroy all seed in the cone. Cones frequently become distorted with a definite curve, or break, as the damage becomes serious. If possible, collection of seed should be avoided in areas where the cone moth is abundant.

69. REITZ, RAYMOND C. 1941. Kiln design and development of schedules for extracting seed from cones. U. S. Dept. Agr. Tech. Bul. 773. 70 pp.

The optimum drying schedule is that combination of temperature, relative humidity, rate of circulation, and time in the kiln which will produce high yields of viable seed at low cost. Cones are relatively expensive compared with the cost of seed extraction, so the drying schedule should be such as to injure no seed. The constant-temperature schedule has been adopted as the most expedient. To develop a schedule for a given kiln type, heat the cones at various temperatures, obtain the released seed after different durations of heating, and test for seed viability. Operators should test the effectiveness of the schedule by simple measurements of cone moisture content, seed yield, seed moisture content, and germination tests.

70. ROESER, J. 1942. The influence of climate on seed production in Douglas-fir. Jour. Forestry 40: 304-307.

No correlation was found between bud production, temperature, and precipitation during the season when the buds are formed or during the preceding season. Weather conditions at the time of flowering in the spring influence flower production. Under favorable conditions the normal percentage of setting is about 90 percent. Freezing weather reduces this. Most of the loss occurs during the early formative period when pollination and fertilization take place.

71. SCHENSTROM, S. R. 1930. A study of reforestation by seeding. Forestry Chron. 6(4): 29-38.

The first and most important factor controlling survival seems to be shade. Mortality has been very high wherever seedlings have been exposed to the sun. Early germination enables seedlings to develop more and to better withstand the drought. Starting simultaneously with other vegetation protects the seedlings more from being eaten because more food is available. Seedlings germinating late in the season are tender while other vegetation has hardened.

72. SCHUBERT, G. H. 1950. Control of sprouting tanoak and madrone stumps. U. S. Forest Service, California Forest and Range Experiment Station Res. Note 74. 2 pp.

Treatment of tanoak and madrone stumps with 2,4-D prevented sprouting of some stumps and reduced the number of sprouts per stump on the others. Treatment was more effective on madrone than on tanoak. Height of tallest sprouts was not appreciably different between the treated and untreated stumps. Season of treatment did not greatly affect control of sprouting. No correlation was found between stump diameter and number of sprouts per stump when a 1 percent water solution of 2,4-D was used.

73. SCHUMACHER, FRANCIS X. 1930. Yield, stand and volume tables for Douglas-fir in California. University of California Agr. Experiment Station Bul. 491. 41 pp.

There are significant differences in certain stand characteristics between Douglas-fir growing north and that growing south of the Willamette-Umpqua divide in Oregon. The growth of Douglas-fir stands in California is shown by tables which state the yield of even-aged stands over a period of years.

Douglas-fir stands break up in California at an earlier age than they do farther north. In California there are fewer trees to the acre throughout the history of a stand, and the number of trees per acre decreases at a greater rate than in the northwest. Young Douglas-fir grows faster in basal area in California, but after about 100 years this growth practically stops, though further north it is still increasing vigorously.

74. SMITH, CLARENCE F. 1947. The influence of mammals and birds in retarding artificial and natural reseeding of coniferous forests in the United States. Jour. Forestry 45: 361-369.

Summarizes Moore's work (References 59 and 60) in the Douglas-fir region.

75. SPENCER, DONALD A. and NELSON B. KVERNO. 1952. Research in rodent control to promote reforestation by direct seeding. Denver Wildlife Res. Lab. Prog. Report 3. 54 pp.

The work to determine if "tetramine" (tetramethylene dilsulpho tetramine) is useful for preventing the consumption of tree seed by rodents is summarized. A technique for treating forest seed without appreciable loss of viability has been developed. Tetramine penetrating the seed hull produced no subsequent reduction in viability during a year's storage. Since tetramine relieves the rodent pressure against the seed, satisfactory germination can be expected under normal conditions. Tree seedlings grown from tetramine-treated seed are also protected against mouse feeding for the first few weeks after germination. Tetramine-treated Douglas-fir seed loses toxicity when exposed on mineral soil over winter but is still strongly repellent against rodents.

76. TARRANT, R. F. 1948. The role of organic matter as a source of nitrogen in Douglas-fir forest soils. U. S. Forest Service, Pacific Northwest Forest and Range Experiment Station Res. Note 48. 5 pp.

Organic matter, as humus, influences such physical soil properties as color, structure, consistency, moisture-holding capacity, and permeability to water and air. Forest soil humus increases the availability of nutrients to the plant, affects soil pH, and provides certain growth-promoting hormones and vitamin-like substances. The humus layers also contain far greater numbers of microflora and microfauna than any of the underlying mineral soil horizons. Soil nitrogen, especially in humid regions, is carried almost wholly by the organic matter, and becomes available to plants only after the organic matter has decomposed to humus. The close relation between organic matter and the nitrogen supply of the Douglas-fir region soils is shown quantitatively. Most of the nitrogen-organic matter content is in the uppermost portion of the forest soil. When the percentage of organic matter of mineral horizons of Douglas-fir region soils is multiplied by the conversion factor .027, an approximate measure of the total soil nitrogen is obtained.

77. ________. 1949. Douglas-fir site quality and soil fertility. Jour. Forestry 47: 716-720.

No significant relation was found between site class and soil reaction (pH), silt-plus-clay content, total nitrogen, available phosphorus and potash, base exchange capacity, replaceable calcium and magnesium, and organic matter. In general the nutrient content of forest soils of the Douglas-fir region appears to be too high to be a limiting factor in tree growth.

78. ________. 1950. A guide for forest soil examination in the Douglas-fir region. U. S. Forest Service, Pacific Northwest Forest and Range Experiment Station. 27 pp.

Outlines some of the important soil terms and procedures and points out to the technician, who is not specifically trained in soil science, the methods used to examine and judge soil conditions.

79. ________. 1950. A relation between topography and Douglas-fir site quality. Jour. Forestry 48: 723-724.

A study considering soil, topography, and site was made. Topography was classified as "convex", including ridges, hilltops and upper slopes, or "concave", including lower slopes, valleys, and basins. Concave topography was associated with significantly higher Douglas-fir site quality than convex topography.

80. U. S. FOREST SERVICE. 1948. Woody-plant seed manual. U. S. Dept. Agr. Misc. Pub. 654. 416 pp.

Seeding habits, seed collection, extraction, storage and germination, and nursery and field practice for Douglas-fir are covered. Good seed crops occur every 3 to 7 years with light crops in the intervening years. An average tree produces about 2½ bushels of cones; an average bushel contains about 1,000 cones. Extract and clean seed as follows:

1. Spread the freshly collected cones out to dry in the sun or place them in a simple convection type cone kiln for 10 to 15 hours at 104°F. (for fresh cones) or 110°F. (for precured cones) and gradually increase the temperature to 130°F.

2. Run the cones through a shaker or flail them to remove the seed.

3. De-wing the seed by running tnem through a de-winger, by kneading them in a sack, or by rubbing them over a one-sixth-inch mesh screen.

4. Clean the seed by fanning or blowing off the chaff.

Douglas-fir seed from California average about 30,000 to 35,000 per pound.

81. WILLIS, C. P. 1914. The control of rodents in field seeding. Soc. Amer. Foresters Proc. 9: 365-379.

Rodents cause 27 to 96 percent loss of artificial seeding. Attempts to make seed repulsive or poisonous to rodents have failed. Wholesale poisoning of an area has failed. (Area poisoned may have been too small, allowing quick infiltration of rodents from borders, or timing may have been wrong. Poisoning too early would allow rodent population to build up.) Efforts to guard the seedspot have been successful. Wire cones have given complete protection but these are too expensive.

82. WILLIS, C. P. 1917. Incidental results of a study of Douglas-fir seed in the Pacific Northwest. Jour. Forestry 15: 991-1002.

Describes various aspects of collecting Douglas-fir cones and extracting the seed. Cones are satisfactory to collect when they first begin to assume a brownish hue. The large seed of a tree are much better in quality than the small ones. Large cones produce large seed and vice versa. Collectors should gather only the larger, better developed cones. Cones must lose at least 35 percent of their weight to open at all well. Not over 40 percent of the green cone weight should be evaporated, for beyond this point drying may injure the seed. Kiln temperatures can be varied satisfactorily depending upon the moisture content of the cones. With green cones a temperature of 100°F. may be satisfactory. Kiln temperatures should be as low as compatible with economy. Seed which do not readily shake from cones are usually of high quality and are worth saving.

83. __________, and J. V. HOFFMAN. 1915. A study of Douglas-fir seed. Soc. Amer. Foresters Proc. 10: 141-164.

The yield of cones per tree is highest with medium-aged, rather large trees, which grow in open stands in warm localities. Some general rules for cone collecting are: Gather cones in a locality as cold as, or colder than the planting site. Avoid extremely high altitudes. Avoid insect-infested cones. Do not collect from sites with shallow, gravelly, or otherwise poor soil. Collect from young or old, small or large trees, as convenient. Seek large cones. Collect from open grown trees where practicable, for they give large yields of good seed per bushel of cones. Avoid trees infected with fungus disease. Average figures for Douglas-fir cones and seed:

Number of bushels of cones per tree	2.46
Number of cones per bushel	1,001
Pounds of mill-cleaned seed per bushel of cones	.41
Number of seed per pound--mill cleaned	38,254
Number of seed per bushel of cones	15,684
Number of seed per tree	39,637
Number of seed per cone	16

84. WRIGHT, ERNEST. 1931. The effect of high temperature on seed germination. Jour. Forestry 29: 679-687.

Seed of certain shrubby plants endured higher temperatures than any other species studied. With few exceptions the germination of shrubby plant seed was raised by the action of heat.